REMARKS

Claims 1-24 are currently pending in the above-identified patent application. In the subject Office Action the Examiner objected to the abstract of the disclosure because the first sentence is not a complete sentence. Applicant has amended the Abstract in accordance with the Examiner's comment. No new matter has been added by this change.

Claims 7, 17 and 18 were objected to because of two informalities identified by the Examiner. Claims 7, 17 and 18 were amended in accordance with the Examiner's instructions. No new matter has been added by these changes.

Claims 1-24 were next rejected under 35 U.S.C. 112, second paragraph as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. The Examiner pointed out that claim 1 recites the limitation "the surface" with reference to the light-incident surface in lines 2, 6, and 7, and "the majority" in line 4. There is insufficient antecedent basis for these limitations in the claims. Claim 3 recites the limitation "the solar cell material" in line 1, and there is insufficient antecedent basis for this limitation as well. The Examiner continued by stating that claim 4 recites the limitation "the surface" in reference to the surface opposite the light-incident surface in line 2, and there is insufficient antecedent basis for this limitation. Claim 9 was found to be indefinite because it is not clear whether the grating has rectangular projections (or grooves) or the grating itself is rectangular. Similarly, claim 10 was found to be indefinite because it is not clear whether the grating has triangular projections (or grooves) or the grating itself is triangular. Claim 12 was found to be indefinite because a solar cell was not claimed in claim 1 and the relationship between the grating and the solar cell is unclear.

The Examiner then stated that claim 13 recites the limitation "the grating surface" in line 2, but that there is insufficient antecedent basis for this limitation in the claim. Claim 15 was identified by the Examiner as reciting the limitation "the surface" in line 2, but that there is insufficient antecedent basis for this

limitation in the claim. Claim 20 was also found to recite the limitation "the surface" in lines 2 and 3, but there is insufficient antecedent basis for this limitation in the claim.

Applicant wishes to thank the Examiner for having pointed out these difficulties and has amended claims 1, 3, 7, 9, 10, 12, 13, 15, 17, 18, and 20 in accordance with the Examiner's concerns. No new matter has been added to the claims as a result of these changes. Claims 1, 15, and 20 have been amended to correct obvious drafting informalities; support for these corrections is found on page 6, lines 11-27, of the subject Specification, as originally filed. The amendment to claims 9 and 10 find support in lines 1-14 of page 8 of the subject Specification, as originally filed, while the amendment to claim 13 finds support on page 13, lines 10-19 of the subject Specification, as originally filed. The dependency of claim 12 was changed to claim 2 after having inadvertently been made dependent from claim 1.

Claims 1-3, 6, 8-10, 12 and 13 were next rejected under 35 U.S.C. 103(a) as being unpatentable over Zaidi et al. in view of Braun et al., since the Examiner asserted that Zaidi et al. discloses a method for increasing light absorption of solar cells by fabricating a diffraction grating on the light-incident surface of a silicon substrate, including both conventional wet and reactive ion etching to form the grating. The Examiner stated that rectangular profile gratings are further disclosed by Zaidi et al., as is coupling the grating to match the solar spectrum. The Examiner continued by stating that Braun teaches a method for forming a grating on a photo detector "to provide low reflectivity surfaces." The Examiner then concluded that it would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the method of Zaidi et al. to use a photo detector as disclosed by Braun because increasing the light absorption of a photo detector would improve the efficiency and performance of the photo detector. The Examiner continued by rejecting the remaining claims under 35 U.S.C. 103(a) over Zaidi et al. in view of Braun and further in view of other references cited by the Examiner.

Claims 15, 16 and 19 were then rejected under 35 U.S. C. 103(a) as being unpatentable over Ruby et al. in view of Zaidi et al. and in view of admissions made in the disclosure, since Ruby et al. discloses a method for forming a solar cell with a random-textured surface to increase light absorption, and a method for cleaning the surface of the substrate using a second etching process. The Examiner concluded that it would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the method of Ruby et al. to form a grating on the surface of the solar cell as taught by Zaidi et al. because Zaidi et al. teaches that "for identically etched structures, uniform structures showed an order of magnitude smaller reflectance than random structures." Moreover, the Examiner concluded that it would be obvious to have modified the method of Ruby et al. to form an n-type junction using gas source doping and to form n- and p-electrical contacts on the solar cell because it is well-known in the art, as is disclosed in the subject application, and to use the step of forming a grating using wet chemical etching because Zaidi et al. teach that wet chemical etching to form uniform structures is well-known in the art. Claims 17 and 18 were rejected under 35 U.S.C. 103(a) as being unpatentable over Ruby et al. in view of Zaidi et al. and admissions made in the disclosure, and further in view of Sakaguchi et al., since although Zaidi et al. does not disclose the method of removing surface damage using wet-chemical etching comprising the step of exposing the surface to KOH and nitric acid solutions, Sakaguchi et al. teach the use of KOH and nitric acid solutions to perform selective etchings. The Examiner then concluded that it would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the method described by Ruby et al., Zaidi et al. and the admissions of the subject patent application to use KOH and nitric acid solutions to clean the surface damage of the solar cell because KOH and nitric acid solutions will selectively and rapidly etch the surface.

Claims 20-24 were then rejected under 35 U.S.C. 103(a) as being unpatentable over Ruby et al. ('021) in view of Zaidi et al., in view of Ruby et al. ('280), and in view of admissions made in the subject disclosure, since the

Examiner asserted that the '021 patent discloses a method for forming a solar cell with a random-textured surface to increase light absorption, and a method for cleaning the surface of the substrate using a second etching process, and concluded that it would have been obvious to form a grating on the surface of the solar cell as taught by Zaidi et al. because Zaidi et al. teach that "for identically etched structures, uniform structures showed an order of magnitude smaller reflectance than random structures." The Examiner stated that the '280 patent discloses a method for forming a junction using ion implantation of phosphorous, a method for heating the solar cell in an oxygen atmosphere, and concluded that it would have been obvious to have modified the method of the '021 patent to form an n-type junction in a solar cell using ion implantation of phosphorous because forming such a junction would provide a cost-efficient method for forming a solar cell junction in the photo-responsive device, and to anneal the solar cell in an oxygen atmosphere because annealing the solar cell in an oxygen atmosphere can form an anti-reflecting and passivating oxide layer on the solar cell.

For the reasons to be set forth hereinbelow, applicant respectfully believes that Zaidi et al. teaches away from the present invention; therefore, the Examiner has improperly combined Zaidi et al. with Braun or with Ruby et al. alone or in combination with other references to meet the burden of a *prima facie* obviousness-type rejection.

Reexamination and reconsideration are respectfully requested.

Briefly, the present invention includes a method for enhancing light absorption in selective spectral ranges by efficient optical coupling of light into obliquely propagating diffraction orders inside a silicon (Si) substrate. Figure 1 illustrates a grating etched on the front surface of a substrate which is characterized by its period d, linewidth l, and depth h. The light is normally incident and the period is chosen such that no diffraction orders in air are present. Due to symmetric profile, equal energy is coupled into the two ±1-diffraction orders and the two ±2-diffraction orders; the fraction of energy coupled into the first and second orders is a complex function of grating parameters. For

improved solar cells, particularly in the space environment, it is desirable that the maximum energy be coupled into those orders propagating nearly parallel to the surface of light incidence; in the present situation, the maximum energy into the two ±2-diffraction orders, and the least energy into the normally propagating zero-order. Additionally, the ±1-diffraction and ±2-diffraction orders are seen to form angles θ_1 and θ_2 respectively, with respect to the surface normal, and that the optical path lengths for these orders are increased by $1/\cos\theta_1$ and $1/\cos\theta_2$ with respect to the zero-order transmitted beam. Thus, for angles, θ, between 30° and 85°, this represents increase in optical path length relative to the zero-order of between approximately 1.15 and 11.5, respectively.

Turning now to the rejection of claims 1-3, 6, 8-10, 12 and 13 under 35 U.S.C. 103(a) as being unpatentable over Zaidi et al. in view of Braun et al., and the other rejections which combine Zaidi et al. with other references, applicant wishes to state that the present invention is counter-intuitive in that the grating structure of Zaidi et al. which significantly reduces reflection of light incident on a surface of a substrate does not channel a majority of this light into light propagating substantially obliquely to the surface of incidence. The grating shown in Fig. 2 of Zaidi et al. is characterized by a period of ~ 0.47 μm, grating projections of ~ 0.05 μm, a depth of ~ 1 μm, and a duty cycle of ~ 0.106). Using these parameters, a diffraction efficiency calculation using GSOLVER™ software was performed. This is a similar calculation to that described on pages 15 and 16 of the subject Specification for a duty cycle of .75 and which give rise to Figs. 20a, 20b and 21 of the subject patent application. The results are shown in Attachment 2 hereof. Figure 1 of Attachment 2 illustrates transmitted efficiencies of 0-order, ±1-diffraction, and ±2-diffaction orders for the TM-polarization (note that the calculations in Figures 20a, 20b and 21 are also for the TM polarization). To be observed is that for the grating of Zaidi et al., all of the incident energy is coupled into the normally propagating zero-order, while almost no energy is coupled into obliquely propagating diffraction orders at a depth of 1-μm. Therefore, although the grating of Zaidi et al. is efficient in coupling almost 75%

of incident energy into the Si substrate, virtually all of this energy is directed into the zero order.

By contrast, the grating structures of the present claimed invention have thicker projections (that is, projections giving rise to duty cycles of ~ 0.75). Diffraction efficiency calculations for the 0.47-μm period grating with Si projections of ~ 0.35 μm are shown in Figure 2 of Attachment 2 hereof. To be noticed is that for the thicker projections (higher duty cycles), significantly greater energy is coupled into obliquely propagating diffraction orders. In this case at a depth of ~ 0.2 μm, ~ 56 % energy is coupled into ±1-diffraction orders, the rest of the energy going into zero-order with almost zero energy into ±2-diffraction orders. This is consistent with the calculations which gave rise to Figs. 20a, 20b and 21 of the subject patent application.

Therefore, the grating structure of Zaidi et al. is designed for reducing reflection; that is, it behaves as an anti-reflection coating, while being substantially unsuitable for the diffractive coupling which is the subject of the claimed invention. In fact, page 13, lines 10-19 and Fig. 18 of the subject Specification, as originally filed, states that the gratings of the present invention may not completely reduce surface reflection from a substrate, and anti-reflection coatings are applied to the grating surface to accomplish this function without interfering with the grating coupling efficiency of the incident light into obliquely propagating modes.

For these reasons, applicant believes that the Zaidi et al. reference teaches away from the subject claimed invention and, therefore, has been improperly combined with the references identified by the Examiner in the rejection of all pending claims under 35 U.S.C. 103(a).

For the reasons set forth hereinabove, applicant believes that claims 1-24, as amended, are in condition for allowance and such action by the Examiner at an early date is earnestly solicited. Reexamination and reconsideration are respectfully requested.

Respectfully submitted,

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